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Designing a monitoring system to detect signals to adapt to uncertain climate change

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ABSTRACT

Adaptive plans aim to anticipate uncertain future changes by combining low-regret short-term actions with long-term options to adapt, if necessary. Monitoring and timely detection of relevant changes, and critical transitions or tipping points is crucial to ensure successful and timely implementation and reassessment of the plan. Although efforts have been made to identify signposts to monitor, the question remains how to design a signal monitoring system that detects and anticipates (future) change to support adaptive planning. For example, to support water related infrastructure investments under uncertain climate change. What are good signposts to monitor and how to wisely analyse them to get timely and reliable signals for adaptation? In this paper, we present a framework for designing and using a monitoring plan as part of the Dynamic Adaptive Policy Pathways (DAPP) approach for decision making under uncertainty. We use the following criteria to evaluate signposts and their critical signal values: measurability, timeliness, reliability, convincibility and institutional connectivity. We illustrate the approach based on the signal monitoring system for the adaptive plan developed by the Delta Programme in the Netherlands.

1. Introduction

Anticipating the future is important when making investment decisions with long-term impacts. However, uncertainties about future needs, conditions, and developments such as climate change, and economic, social and technical developments, complicate our ability to anticipate and make decisions. Adaptive plans are being advocated to deal with uncertainties about the future and minimise regret (e.g. Walker et al., 2013). Adaptive plans consist of short-term actions, which are typically low-regret actions that keep future options open, and long-term alternatives to adapt to uncertain changing conditions, if necessary.

Several approaches exist to design adaptive plans, including Assumption Based Planning (ABP) (Dewar et al., 1993), Adaptive Policy Making (APM) (Kwakkel et al., 2010a; Walker et al., 2001), Robust Decision Making (RDM) (Lempert et al., 2003), Multi Objective Robust Decision Making (Kasprzyk et al., 2013), Engineering Options Analysis (EAO) (Smet, 2017), and Dynamic Adaptive Policy Pathways (DAPP) (Haasnoot et al., 2013). These approaches all share the central idea that the best way to deal with uncertainty is to do what needs to be done now, and to watch out for changes that indicate that new decisions are required to address changed conditions (e.g. Swanson et al., 2010). Two types of adaptive plans are distinguished in the literature (Kwakkel and Haasnoot, 2018; Maier et al., 2016): 1) protective or static adaptiveness, which aims to protect a basic plan from failing through contingency planning and monitoring (example approaches are ABP, APM, and RDM); and 2) dynamic adaptiveness, which aims to monitor the ability of the plan to meet objectives and developing alternative sequences of actions over time that can be switched to when required (example approaches are DAPP and EOA).

Approaches for adaptive plans have strong roots in the fields of water and infrastructure management, transport, and defence. The related idea of adaptive management (Holling, 1978, 2001) originates from ecosystem management (Swanson et al., 2010). Adaptive *management* focuses on increasing adaptive capacity of the system by learning from experiments (Arvai et al., 2006; Bormann et al., 1994; Pahl-Wostl et al., 2007). This suggests an important role for monitoring the performance of the system. Adaptive *planning* uses monitoring for decision making on follow-up actions of a plan.

The success of adaptive plans thus depends on monitoring and

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anticipating on-going developments (e.g. climate change and socio-economic change) and ensuring that actions are indeed taken if and when necessary, or that the plan is updated in case of unforeseen developments. In general, monitoring and evaluation aims to learn and improve the progress of implementation of a plan, its process and the efficacy of the actions in achieving specified goals. Preston et al. (2011) provide a literature review on monitoring and evaluation of adaptation planning to climate change. Most of these studies focus on procedural aspects, adaptation progress, elements of the plan and governance support (e.g. Ford et al., 2013; Biesbroek et al., 2010; Klostermann et al., 2018; Marsden and Snell, 2009). These studies typically look back and try to answer the question: 'Are actions implemented as planned and are they effective?' This can therefore be considered as *retrospective* monitoring, and is typically done in adaptive management, where monitoring aims to learn from an experiment. In contrast, adaptive planning requires also *anticipatory* monitoring, which focuses on the question: '(When) should actions be implemented and are they still appropriate?' It thus aims to anticipate uncertain future developments that could trigger implementation or adjustment of adaptive plans to new information. Essential for anticipatory monitoring is to acknowledge that, before an action becomes effective, it takes some time to study, prepare and implement it ('lead time'). An adequate amount of time therefore required between signal and the envisioned new situation.

The idea of anticipatory monitoring originates in literature from strategic planning (Schwartz, 1996) and Assumption-Based Planning (Dewar et al., 1993). These approaches suggest monitoring of important assumptions underlying a plan to establish if these assumptions are at risk and whether additional actions need to be taken. Signposts specify the information or indicators that should be tracked. Critical values of these signposts – sometimes referred to as triggers – are used to determine when follow-up actions should be implemented, including contingency actions or next actions of an adaptation pathway.

Approaches and practices of anticipatory monitoring are often generic instead of plan-oriented. Such generic approaches examine seeds of change and monitor developments and possible events that may have an impact on a market, a sector, an organization or a policy domain in general. Some of these approaches have a strong foothold in strategic planning and futures studies, such as Trend Analysis and Horizon Scanning (OECD, 2017), whereas other approaches, such as Early Warning Systems (e.g. Waidynatha, 2010) and Security Analysis (the analysis of security threats for a sector or organization), stem from a tradition of Risk Analysis. Monitoring for Early Warning Systems and Security Analysis is based on the identification of threats and hazards. Trend analysis and horizon scanning often add two other aspects: possibility and desirability. Possibility considers the likelihood of the trend in light of other trends or natural law. Desirability deals with the preference for (or against) a certain trend, and if there are any advantages (or not) to a trend developing (Cramer et al., 2016). The information is used to score and classify and to gain a deeper understanding of the nature and meaning of existing and potential new trends and developments.

While examples exist on what needs to be monitored to support adaptive plans and efforts have been made to find early warning signals (e.g. Scheffer et al., 2009; Schoemaker and Day, 2009), yet the identification of proper signals remains a challenge (Garschagen and Solecki, 2017). So far, most studies have used expert judgement (e.g. Kwakkel et al., 2010b; Lempert and Groves, 2010; Environment Agency, 2012; Haasnoot et al., 2013; Groves et al., 2015; Kingsborough et al., 2016; Hermans et al., 2017; Tariq et al., 2017), model-based vulnerability assessment (Bryant and Lempert, 2010) and/or optimisation methods (Hamarat et al., 2014; Kwakkel et al., 2016; Quinn et al., 2017) to design signposts and related critical values for signals. A first attempt to evaluate the performance of expert-based signposts was done using transient scenarios (Haasnoot et al., 2015). The governance around monitoring to support collaborative learning for adaptive planning has been addressed in terms of who should monitor what and for whom by Hermans et al. (2017).

To design a signal monitoring system to support adaptive planning and derive proper signals for adaptation, the following questions need to be addressed: How to decide what to monitor? How to best analyse the derived information to get timely and reliable signals that are convincing for the responsible people to act upon?

In this paper, we present a framework for designing and using a signal monitoring system to inform adaptive planning and illustrate this for water related infrastructure investments. We describe how to identify signposts to monitor and establish critical values to derive signals and provide criteria and examples on how to evaluate them. We present the framework as part of the Dynamic Adaptive Policy Pathways (DAPP) approach, but it can be used for other adaptive planning approaches as well. The pathways approach has demonstrated significant potential as an adaptive planning approach to support decision making on water management under conditions of deep uncertainty both in literature and in practice (e.g. Haasnoot et al., 2012; Ranger et al., 2013; Barnett et al., 2014; Wise et al., 2014; Rosenzweig and Solecki, 2014; Bloemen et al., 2017; Lawrence and Haasnoot, 2017; Stephens et al., 2017; Zevenbergen et al., 2018). Although, most applications are on water resources and flood management, the approach has been used in other policy domains as well (Petr et al., 2015; Bossomworth et al., 2017; Mendizabal et al., 2018).

This paper first describes the concept of adaptive planning and the role of monitoring and signals therein. Next, the case study – the Delta Programme in the Netherlands – is introduced (Delta Programme, 2015; Bloemen et al., 2017). We then present the framework on how a signal monitoring system can be designed and illustrate this based on the adaptive plan of the Delta Programme. We end the paper with discussion on the approach in the light of the defined criteria.

2. Adaptive planning, policy pathways and the importance of monitoring and signals

2.1. Adaptive planning through Dynamic Adaptive Policy Pathways

Adaptive planning means that short-term actions and long-term options have been identified, and that monitoring and signalling supports timely implementation or adjustment of the specified plan.

Adaptive plans can be developed using the Dynamic Adaptive Policy Pathways (DAPP) approach (Haasnoot et al., 2013). Within the DAPP approach a plan is conceptualized as a series of actions over time (pathways). The approach starts from the premise that policies, actions, or decisions have an uncertain design life and might fail to achieve their objectives sooner or later; when operating conditions change they may reach an adaptation tipping point (Kwadijk et al., 2010). Likewise, when favourable conditions arise actions may reach an opportunity tipping point to implement actions, for example if benefits exceed costs (Bouwer et al., 2018). Once actions fail, additional or other actions are needed to ensure that the original objectives are still achieved, and a set of potential pathways emerges. There are different routes that can achieve the objectives under changing conditions (analogous to 'All roads lead to Rome'). Hence, various alternative sequences of decisions or actions can be explored for multiple futures. Depending on how the future unfolds, the course of action can be adapted when predetermined conditions occur to ensure that the objectives are still achieved.

Multiple pathways are typically visualized in an Adaptation Pathways Map or decision tree, with time and/or changing conditions on the axes (Fig. 1). With this map, it is possible to illuminate opportunities, no-regret actions, lock-ins, path-dependencies, and the timing of options. An adaptive plan is then designed based on an evaluation of the alternative pathways.